whether some of them, full of the new light to which they had attained abroad, may not have overlooked the merits and ignored the researches of older investigators at home, or even confounded old discoveries with new: all this we need not stop to inquire. Suffice it to say, that although this was no more than might have been expected in some instances, we do not think that the maligners of these gentlemen could give chapter and verse for much of what they allege against them.

But the leaders of the new school deserve at least a fair hearing; and we are happy that they are now having opportunities of speaking for themselves to the British medical public; for, without saying that they are infallible, or the most illustrious men that ever lived, or any other of the absurdities which have been imputed to their admirers, we doubt not that any reader whose opinion is of the least value will find, in the perusal of such books as that now before us, ample proof that Dutchmen and Germans are still as able as ever to execute good solid work in the domain of medical science and practice. Nay, we are convinced that the more any candid reader of this work has previously occupied himself with its subject, the more will he be delighted with the clearness which it imparts to his views on many intricate questions, and amazed at the ingenuity and enormous industry of which it gives evidence.

Several abstracts of Donders' views on particular departments of physiological and pathological optics have recently appeared in English; but these, however useful as introductions to the study, are necessarily elementary in their character, and somewhat limited in their scope. We have now a comprehensive treatise on the anomalies of refraction and accommodation, prepared for publication in English by Donders himself, and translated from his manuscript under his own supervision.

This work may be regarded as an extension of former essays on different departments of the subject, revised and amended in the light of the most recent researches. The author, in his preface, states his design in the following terms:—

"One object I have kept constantly in view,—to make the book, notwithstanding its great size, useful and, in all its parts, easily accessible to the practical physician. To this end, in the first place, each subject is fully treated of in the body of the text; consequently, only those who wish to penetrate more deeply into the subject, need attend to the details of the investigation, to the mathematical demonstration, and to the history, added as an appendix, in smaller type.

And, in the second place, to facilitate reference to the several parts, each chapter is so drawn up, that the reader's knowledge of what has gone before, is not taken for granted. The work forms, in a certain sense, a series of lesser monographs, united in a single volume, which is the emblem of their mutual connexion"—(pp. vii, viii).

This method of arranging the contents of a book necessarily involves a little repetition; and, in order to avoid this in our detailed review of the several chapters, we shall endeavour, first of all, to give a sketch of some elementary topics, the knowledge of which, on the part of our readers, we shall afterwards take for granted. If this introduction should prove superfluous in the case of many, it may be useful to those who have not hitherto made the eye their special study; and it may serve as a basis for the exposition of facts, and the explanation of terms—some of them of recent origin—to which we must allude when we come to take up the chapters in detail.

The human eye, considered as a mere optical instrument, may, to use a hackneyed illustration, be compared to a camera-obscura, like those employed by photographers. Such an instrument is made up of a refracting apparatus, consisting of a lens or lenses, of a chamber to which light is admitted through the refracting apparatus, which fills an aperture in one of its walls, and of a screen, forming the opposite wall, for the reception of the light so admitted. The refracting apparatus or object-glass of the camera produces, whether it is simple or compound, an effect upon the light refracted by it similar to the effect produced by a common biconvex lens. Rays of light, proceeding from a given point, and refracted by such a lens, are rendered less divergent than before, or they are rendered parallel to one another, or they are made to converge towards another point, after passing through the lens, according as they come from a point nearer to the lens than its principal focus, or at its principal focus, or farther from it than its principal focus. Rays which converge towards a point beyond the lens, before they strike upon it, are so refracted, that, after they have passed through it, they converge still more towards a point nearer the lens than its principal focus.*

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* Concave lenses, of which we shall have to speak afterwards, produce effects opposite to those of convex lenses. They increase the divergence of divergent rays; they render parallel rays divergent; and they render convergent rays less convergent, or parallel, or divergent, according to the degree of convergence which they had before refraction.

The point where the direction-lines of the rays composing one set or pencil

To revert to our illustration—rays of light radiating from each point in a distant object, and falling upon the object-glass, are made to converge towards and intersect one another in corresponding points, after they have passed through it; and if the screen stands at the proper distance from the object-glass, nearly in the plane of its principal focus, these rays will strike it just as they have reached their points of intersection. Each illuminated point in the object has now a corresponding illuminated point on the screen; and as these points preserve mutual relations nearly similar to those of the corresponding points in the object, though in an inverted order, they form an inverted image of the latter.

This inversion of the image is due to the fact, that while the rays composing the fasciculus, which comes from any one point in the object, have their mutual divergence altered to convergence, the general direction of the fasciculus to which they belong is maintained after refraction. Those which come downwards from a point in the object above the level of the lens proceed downwards after they have

intersect one another is termed a *focus*. Rays which have thus a common focus before refraction have a common focus after refraction by a properly centred lens or system of lenses, convex or concave. That is to say, if the direction-lines of the rays intersect one another in one point before refraction, they will intersect one another in one point after refraction. These points are termed *conjugate foci*, and their respective distances from the centre of the lens are termed *conjugate focal distances*.

The only exception to this occurs when the rays proceed parallel to one another before or after refraction. In this case they have, properly speaking, no focus; their direction-lines do not intersect one another; but they are regarded as having a focus at an infinite distance from the lens, and the conjugate focus corresponding to it is a point termed the *principal focus* of the lens. There are, thus, two principal foci, one on each side of the lens; they are equidistant from its centre; and their distance from it is termed the *principal focal distance*. If the rays, before refraction by a *convex* lens, diverge from the first principal focus, they will proceed parallel to one another after refraction; and if the rays are parallel to one another before refraction, they will converge after refraction, and intersect one another in the second principal focus. Again, if the rays, before refraction by a *concave* lens, converge towards the first principal focus which, in this case, is beyond the lens, and in which they would intersect one another but for the interposition of the lens, they will proceed parallel to one another after refraction; and if they are parallel before refraction, they will diverge, after refraction, as if they came from the second principal focus, where their direction-lines, if traced backwards, will intersect each other. The principal focal distance of convex lens is regarded as positive; and the principal focal distance of a concave lens is regarded as negative, and has the negative sign prefixed to it in Donders' work—a practice the reverse of what has been usual in English books on general optics.

passed through it, and unite at a point below the centre of the screen; those coming from below proceed upwards and unite in a point above the centre of the screen; and so on.

The human eye possesses a system of lenses forming a sort of compound object-glass, and corresponding to the object-glass of the camera. This system is composed of the cornea and aqueous humour, together with the crystalline lens. Instead of a rectilinear chamber filled with air and bounded by plane surfaces, as in the camera, we have, in the eye, a cavity containing the vitreous humour and bounded by the curved internal surface of the ocular tunics, over a great part of which is spread the retina, corresponding to the screen in the camera, but much better adapted by its form to receive an accurate picture of all parts of the object than is the plane surface presented by the screen. In so far as distinct vision depends on the optical construction of the eye, the grand condition is, that an accurate image of the object should be projected on the retina. The provisions for fulfilling this condition under various circumstances, and the optical defects which prevent its fulfilment, constitute the topics to be discussed in this review.

If the distance between the object and the refracting apparatus of a camera obscura is very great, relatively to the principal focal distance of the latter, we may regard it as practically infinite; and if the screen lies in the plane of the principal focus of the object-glass, it will then receive an accurate picture of the object. In these circumstances, the camera represents what Donders terms an *emmetropic* eye, with its internal muscular system in a state of repose or relaxation. The emmetropic eye is so formed, that when it is in a state of repose, the principal focus is on the retina; and rays, which pursue directions parallel to one another before refraction, are united in a single point on the retina after refraction. The name *emmetropia* (from *ἔμμετρος*, *modum tenens*, and *ὤψ*, *oculus*) is applied to this condition or formation of eye, because it is regarded as the standard or normal one, in so far as concerns the relation between the conformation of the eye and the refracting power of its dioptric apparatus. Such an eye may be abnormal in other respects; and hence the propriety of choosing a name which indicates nothing more than the existence of a certain harmony between the dimensions and the refracting power of the organ.

In fig. 1, taken from Donders, we have a diagrammatic representation of the emmetropic eye. The parallel rays are made to converge by refraction at the cornea and lens, and come to a focus in φ'' on the retina.

But the harmony of which we have been speaking does not always exist; and hence we have to distinguish states of *ametropia*, in which a due proportion between the principal focal distance of the eye and the length of its antero-posterior diameter is found wanting.

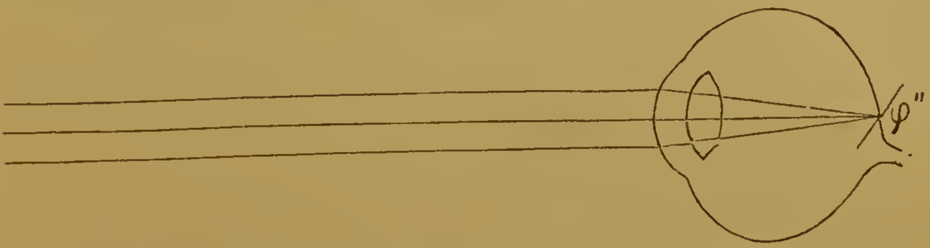

Fig. 1.

If a photographer, about to take a view of distant objects, were to draw back the screen of his camera till it stood far behind the principal focus of the object glass, the rays coming from any one point in the object would cross one another before they reached the screen; and, consequently, each point in the object would be represented on the screen, not by a point, but by a circle of some magnitude. The circles on the screen, representing adjacent points in the object, would then overlie each other; and the result would be the formation of a confused and indistinct, instead of a sharply defined, picture. When an eye in its relaxed state presents this condition, it is termed *brachymetropic*, or, to use an older and better known term, *myopic*. The principal focus lies in front of the retina, and distant objects cannot be distinctly seen. If the object approaches the eye, so that the extreme rays coming from each point in it and entering the organ, become more and more divergent, instead of being virtually parallel before refraction, the retinal image will grow more and more distinct, till at length it is quite sharp. The conjugate focus of a point on the object now lies on the retina.

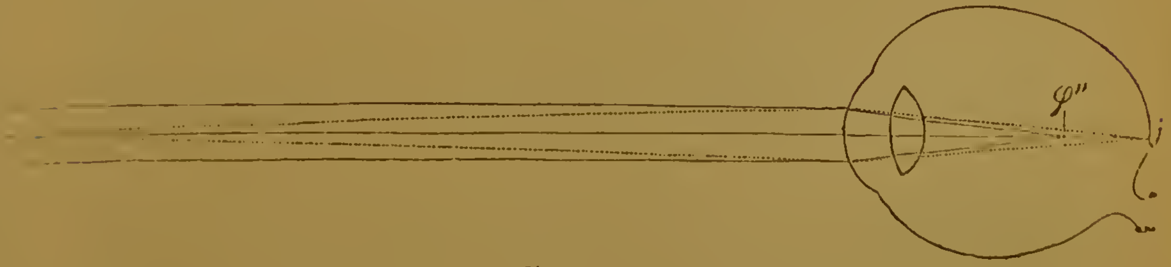

Fig. 2.

Fig. 2 represents a myopic eye. Parallel rays intersect one another after refraction, in the point φ'', the principal focus, which is in the vitreous humour. Rays diverging from the point *i*, and represented by the dotted lines, are refracted by the eye so as to intersect one another at j on the retina. The point i will be distinctly seen; and i and j are conjugate foci.

When the principal focus is *behind* the retina of an eye in a state of relaxation, Donders applies the term *hypermetropia* to the condition, and the eye is said to be *hypermetropic.* In this condition, no objects, whatever be their distance, can be distinctly seen, except by the intervention of a lens, or by the exercise of an accommodating power of which we shall come to speak presently.

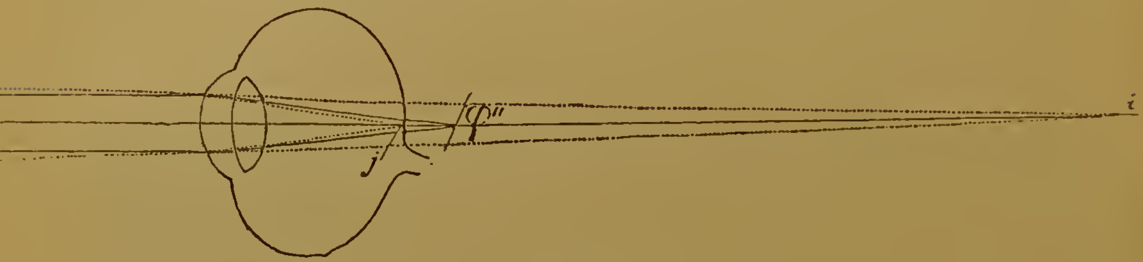

Fig. 3.

Fig. 3 represents a hypermetropic eye. Its principal focus lies in ϕ'', behind the retina. The parallel rays, represented by continuous lines, converge, after refraction, towards ϕ''; but they are intercepted by the retina before they reach that point; and they form a circle of dispersion round the point j on the retina. Thus, a point, even remote from the eye, is indistinctly seen; and nearer points, still more indistinctly. If the rays, however, are made to converge (as might be done by means of a convex lens) towards the point i, which is the focus conjugate with j on the retina, these convergent rays, represented by the dotted lines, are made to converge still more, and to unite on the retina in the point j.

In employing the terms *emmetropia*, *brachymetropia*, and *hypermetropia*, Donders has taken, as the measure of the proportion or disproportion existing between the refracting power of the eye and its antero-posterior diameter, the position and distance of the point which is the focus conjugate with the point where the optical axis, or, what comes to the same thing, the visual line,* cuts the retina. Thus, in the *emmetropic* eye (fig. 1), the point ϕ'' on the retina, being the principal focus of the eye, has its conjugate focus[*] at an infinite distance from the eye; and this is taken as the standard. In the *myopic* eye (fig. 2), the point j on the retina has its conjugate focus at i, situated at a finite distance in front of the eye—a distance shorter than infinity;—hence the term *brachymetropia*, which, however, is seldom used. In the *hypermetropic* eye (fig. 3), the point j on the retina has its conjugate focus at i—a point behind the eye instead of in front of it. The standard measure or limit to the distance of i is here exceeded; for this point is regarded, in a transcendental sense, as lying beyond infinity;—hence the term *hypermetropia.*

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* The *optical axis* is a straight line drawn through the centres of the refracting surfaces, so as to cut them at right angles. Strictly speaking, no single straight line does so; but as the axes of the different refracting surfaces in the human eye are nearly, though not exactly, coincident, we may regard them as having a common axis. The *visual line* is a straight line drawn from the fovea centralis in the yellow spot to the point on which the eye is directed. It very rarely coincides with the optical axis; but, from the form of the retina, the points where the

If the photographer's camera admitted of no change in the relation of its parts, he would be unable to obtain distinct pictures of near or distant objects at will. In like manner, the emmetropic eye could only see distant objects distinctly; the myopic eye could only see objects at one particular finite distance distinctly; and the hypermetropic eye could see no object in nature distinctly, unless the eyes were supplemented by artificial appliances, or were capable of undergoing some change in their optical relations.

In the camera obscura, the necessary alteration is effected by increasing the distance between the object-glass and the screen, the shorter the distance between the object and the camera. When the eye has to adjust itself for a nearer object, the distance between the cornea and the retina remains unchanged; but the surfaces of the crystalline lens become more strongly curved—especially its anterior surface;—and the lens may be regarded, at the same time, to have moved somewhat forward, in a certain sense; for, while its posterior pole occupies nearly the same position as before, its axis becomes elongated, in consequence of the increased curvature of the surfaces.

The effect of all this is, to shorten the focal distance of the whole apparatus. In the emmetropic eye, the principal focus comes to lie in front of the retina, instead of being upon it; and thus, a point at a finite distance in front of the eye comes to have its conjugate focus on the retina; and objects at that distance are distinctly seen. Corresponding changes occur in the case of myopic and hyperme-

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optical axis and the visual line cut the retina, have their conjugate foci at equal distances from the eye and although their conjugate foci are not usually coincident, their positions are so far similar, that they are either both in front of the eye, or both behind it.

[*] Corresponding to the point i in figs. 2 and 3.

tropic eyes, so that the latter are generally capable of adjustment for objects at finite distances in front of them.

This process, whereby the eye adapts itself to different distances, is termed *accommodation.* When we accommodate the eye for a nearer point than before, *i.e.,* when we shorten its focal distance, the internal change which takes place is believed to be of an active character, depending on contraction of the ciliary muscle. When we adjust the eye for a more remote point than before, the change seems to be caused by a passive relaxation of that muscle.

The nearest point of distinct vision is commonly termed the *near-point,* or *nearest point;* and the most distant, the *far-point,* or *farthest point.* When the accommodative power is not in exercise, the eye remains adjusted for the *farthest point,* which corresponds to the point *i,* in figs. 2 and 3. As we have already seen, it is upon the position of this farthest point that Donders bases his classification of eyes into *emmetropic,* where the farthest point is at an infinite distance, *brachymetropic,* where the distance between the eye and the farthest point is finite, and *hypermetropic,* where there is, properly speaking, no farthest point. In this last case—to make use of a convenient paradox—the farthest point may be said to lie beyond infinity ; it is behind the eye instead of being in front of it ; it is the point towards which rays must converge before they enter the eye, in order that they may come to a focus at the intersection of the optical axis and the retina, after refraction in the eye.

Before proceeding farther, we shall state, in his own words, the definitions which Donders gives of the terms *refraction* and *accommodation* of the eye, and the distinction which he makes between *defects of refraction* and *defects of accommodation;* because he employs the term *refraction* in a somewhat restricted sense, and it is only in this sense that defects of *refraction* could, with propriety, be opposed to defects of *accommodation.*

"By *refraction of the eye,* we understand its refraction in the state of rest ; that is, the refraction which the eye possesses in virtue of its form and of that of its component parts, independently of muscular action, independently of accommodation. The term, therefore, applies to the refraction of the eye whose muscles of accommodation are inactive or paralyzed (for example, under the influence of atropia), to the refraction also of the dead, but as yet otherwise unaltered eye."

* * * * *

"*Accommodation is, therefore, the voluntary action whereby the eye* *becomes adjusted to a nearer point than is the case in the state of rest of accommodation.*" *

"The difference between lesions of refraction and of accommodation is deducible from the words themselves. The lesions of refraction are to be sought in the structure of the eye, in the condition of rest, without attendant action of accommodation. The disturbances of accommodation, on the other hand, have their foundation in abnormal action of the internal muscular system of the eye." †

From this it will be understood that myopia and hypermetropia, the two opposite conditions of ametropia, are defects of refraction.

The position of the farthest point being given, that of the nearest point depends upon the degree of accommodative power possessed by the individual; and that varies according to age and other circumstances.

From what has been said, it may be inferred that, with the same degree of accommodative power, the *regions*, within which objects may be distinctly seen by eyes of different conformation, may differ widely as regards their position. Not only so, but these regions may differ widely as regards their extent; and therefore the magnitude of the region of accommodation is not directly proportioned to the amount of accommodative power; and it is not so, even in the case of eyes, similar in their optical conformation, but differing in accommodative power.

Now it is desirable, for the purposes of clinical observation and comparison, to have an expression for the degree of accommodative power, or, in other words, for the *range* of accommodation as distinguished from the *region* of accommodation—an expression which shall be easy in its practical application. To measure directly the changes which take place in the focal distance of an eye during accommodation, would be impracticable under ordinary circumstances; and it would be useless for purposes of comparison, because eyes, similar in their optical capabilities, may differ in their actual dimensions. We have, however, in the respective distances of the farthest and nearest points, the basis for an expression of the practical value of the accommodative power, and one easily found and applicable to all cases.

As there are several refracting surfaces in the human eye, rays refracted by them undergo a series of deflections before they enter the vitreous humour; but, in order to simplify the matter, we may represent all these deflections as taking place in one plane. In our present illustration, it does not matter much whether we imagine this plane to be placed at the cornea, or somewhat more deeply seated in the eye.

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* P. 80.

† P. 2.

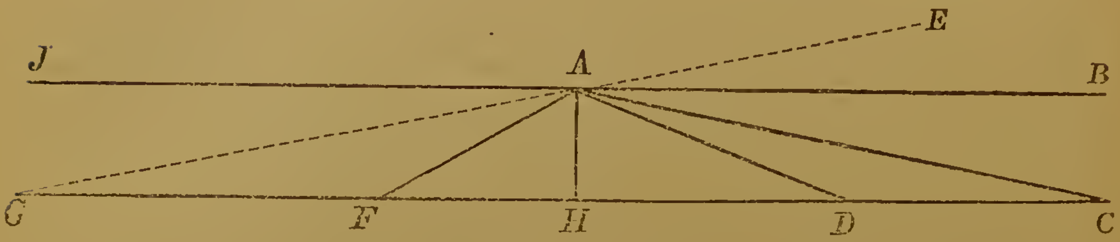

Fig. 4.

Let the straight line G C (fig. 4) represent the optical axis of an eye; let F be the point where this axis meets the retina; and let A H, at right angles to the axis which it cuts in H, be the plane in which the refraction takes place. In the following demonstrations, the distance of A from H is always supposed to be the same; and, in each of them, we shall confine our attention to rays refracted at the point A.

If the eye is *emmetropic*, with its accommodation in abeyance, the principal focus is at F; and a ray, B A, parallel to the axis, will be deflected at A so as to meet the axis in F. If the eye now accommodates itself for the point C in the axis, its nearest point, rays from C will be brought to a focus on the retina in the point F. In order that this may take place, the focal distance of the eye must be shortened, so that the principal focus comes to lie between F and H, which is equivalant to an increase in the refracting power of the whole instrument. If the ray C A is to meet the retina at F, it must undergo a deflection greater than that which took place in the case of the ray B A; and this additional deflection is represented by the angle B A C=A C H. This angle may be taken as the practical measure of the change which has taken place in the refracting power of the eye; provided that in our future comparisons we preserve the distance between A and H unaltered.

Let us now suppose the eye to be *myopic*, with its farthest point at C, and the point where the axis meets the retina still at F. The principal focus lies between F and H; and, if the eye is adjusted for its farthest point, the ray C A will be deflected at A so as to meet the axis at F. If the nearest point lies at D, and the eye accommodates for the point D, the ray D A is deflected at A so as to cut the axis in F, and it undergoes a deflection greater than that of the ray C A by the angle C A D. The angle C A D is, in this case, the measure of the range of accommodation.

Again, let us suppose the eye to be *hypermetropic.* F is still the point where the axis cuts the retina; but the principal focus is behind F. In order that rays may come to a focus at F, when the accommodative power is not in exercise, they must converge before refraction towards some such point as G, behind the eye. G and F are conjugate foci; and the ray E A, proceeding towards G, is refracted at A so as to meet the axis at F. G is here regarded as the farthest point. Let us now suppose that, with the greatest tension of accommodation, the principal focus comes to lie in F, upon the retina. The eye is now adjusted for parallel rays, and the ray B A, parallel to the axis, is deflected at A so as to cut the axis in F. The additional deflection which measures the range of accommodation is here represented by the angle E A B=A G H.

We now wish to find expressions for the comparative magnitudes of these angles, which represent the ranges of accommodation, in terms of the distances of the respective farthest and nearest points, measured from H.

It will be most convenient to consider the case of the *myopic* eye in the first place. Its nearest point is at D, and its farthest point is at C; and its range of accommodation is measured by the angle C A D=A D H—A C H.* If the distance A H is assumed to be infinitesimally small in proportion to the other distances concerned, we may regard the angles A D H and A C H as inversely proportioned to the distances H D and H C respectively. This relation is expressed by the reciprocals of the numbers expressing the distances; so that A D H — A C H becomes $\frac{1}{H\,D} - \frac{1}{H\,C}$ = C A D = range of accommodation.

In the case of the *emmetropic* eye the distance of the nearest point is H C, and that of the farthest point is infinity. The range of accommodation is represented by the angle A C H, or, as it may be stated, A C H — O, or $\frac{1}{H\,C} - \frac{1}{\infty}$.

In the case of the *hypermetropic* eye, the distance of the farthest point is H G, to which we prefix a negative sign to show that it is measured from the eye in an opposite direction to our previous measurements; that of the nearest point is infinity; and the range of accommodation is represented by the angle A G H, or $\frac{1}{\mathrm{H\,G}}=0+\frac{1}{\mathrm{H\,G}}$; but as H G is negative, we may prefix the negative sign, and write it $0-\frac{1}{-\mathrm{H\,G}}$ or $\frac{1}{\infty}-\frac{1}{-\mathrm{H\,G}}$.

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* Because A D H, being the exterior angle, is equal to the sum of the two interior and remote angles of the triangle A D C. Hence, A D H = C A D + A C H and C A D = A D H – A C H.

Supposing again, that this hypermetropic eye had so great a range of accommodation that its nearest point lay at C, the range would be represented by the angle E A C=A C H+A G H, or $\frac{1}{\mathrm{H\,C}}-\frac{1}{-\mathrm{H\,G}}$.

Thus, in all cases, the range of accommodation may be represented by the difference between the reciprocals of the distances of the nearest and farthest points respectively. Donders has fixed on general expressions to represent the nearest and farthest points, and their distances from the eye. He represents the nearest point by the letter *p*, the farthest point by *r*, the distance of the former by capital P, and that of the latter by R. If we substitute these letters for those in the formulæ obtained above, we shall get in each case the general expression $\frac{1}{\mathrm{P}}-\frac{1}{\mathrm{R}}$ for the range of accommodation.

Supposing that the eye remained in its relaxed state, without undergoing any accommodative change, effects similar to those caused by accommodation might be produced, if we had the power of adding to it an auxiliary lens; and the refracting power of this lens would measure the accommodative power, and range of accommodation for which it was substituted. Let us imagine an auxiliary convex lens of this sort, infinitesimally thin, and applied infinitesimally near to A H in figure 4. If the eye were emmetropic, the lens would enable rays proceeding from C to come to a focus at F on the retina, provided its focal distance were equal to the distance H C. The ray C A would be rendered parallel to the axis by the lens, and it would take the direction B A; after which the refraction of the eye itself would be sufficient to deflect it towards F on the retina.

The refracting power of such a lens may be measured by the same angle which has been already shown to measure the range of accommodation, viz., the angle formed by the direction-line of a ray proceeding from the nearest point of the eye towards the point A, and that of a ray proceeding from the farthest point towards the point A—provided that the lens is actually applied to H A, and that the axes of the eye and lens coincide.* The power of a lens, moreover, is inversely proportioned to its principal focal distance; and it is expressed by the reciprocal of the latter. Thus, in the present case where the focal distance of the imaginary lens is = H C, the power may be taken as $\frac{1}{\text{H C}} = \frac{1}{\text{H C}} - \frac{1}{\infty}$, which was the expression already obtained for the range of accommodation in the emmetropic eye, with its nearest point at C.

In like manner, an auxiliary lens, which, when placed at A H, would deflect the ray D A in the direction C A, or the ray B A in the direction E A, would represent by its refracting power the range of accommodation in the case of the myopic and hypermetropic eyes, respectively; and thus the angles, A D H — A C H, and A G H, represent the power of the lenses required as substitutes for accommodation in these two cases. These angles are to one another as $\frac{1}{\text{H D}} - \frac{1}{\text{H C}}$ is to $\frac{1}{\infty} - \frac{1}{-\text{H G}}$, as we have already seen.

If we represent the focal distance of the lens, required in any case by A, its refracting power is represented by the reciprocal $\frac{1}{\text{A}}$; this also represents the range of accommodation; and we have now the equation $\frac{1}{\text{A}} = \frac{1}{\text{P}} - \frac{1}{\text{R}}$. This general expression is much used by Donders in the course of his work, $\frac{1}{\text{A}}$ being the symbol employed by him for the range of accommodation, and $\frac{1}{\text{P}} - \frac{1}{\text{R}}$ being its equivalent.

If we suppose the distances H C and H G to be, each of them, 8 inches, and the distance H D to be 4 inches, the *ranges* of accommodation represented by $\frac{1}{\text{H C}}$, $\frac{1}{\text{H D}} - \frac{1}{\text{H C}}$, and $\frac{1}{\text{H G}}$, are all equal to one another; for they may be expressed thus $\frac{1}{8}$, $\frac{1}{4} - \frac{1}{8} = \frac{1}{8}$, and $\frac{1}{8}$; but the *regions* differ very much in extent. The emmetropic eye in our illustration can accommodate for any distance greater than 8 inches; its region is therefore infinite. The hypermetropic eye has also a region infinite in extent, though differing in position from that of the emmetropic.

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* Because the accommodative change in the one case, and the lens in the other, sufficed to deflect a ray coming from the nearest point into the direction which it would have pursued had it come from the farthest point; and because all rays whose direction-lines, before refraction, intersect or are parallel to the axis of the same lens, will be deflected in the same degree by refraction at the lens, provided the refraction takes place in each case at the same distance from the axis, and provided that the lens is infinitesimally thin.

The myopic eye has a region limited to the 4 inches between C and D. It is important to keep this distinction between the range of accommodation $(\frac{1}{P}-\frac{1}{R})$ and the region of accommodation (R—P) in mind; because great confusion will result if it is neglected.

If an eye is myopic or hypermetropic, the degree of its ametropia may be represented in a manner similar to that employed in measuring the range of accommodation. As has been already stated, Donders bases his classification of eyes, in respect of their refracting power, upon the position of the farthest point; and, accordingly, in determining the degree of ametropia which may be present, we must suppose the eye to be accommodated for its farthest point. The distance of this point, in emmetropia, is infinite. If the farthest point is not situated at an infinite distance from the eye ametropia is present; and the degree of the ametropia may be measured by the power of the lens required to correct it; while its nature is indicated by the quality of that lens. The lens in question must be of such a kind, that, if it were added to the eye, the farthest point of the whole apparatus (eye and lens together) would lie at an infinite distance; and the principal focus of the whole apparatus would lie on the retina of the eye.

Suppose that the farthest point of the eye lay at C (fig. 4). The eye would be myopic; and it is desired to find a lens which, when added to it, would enable the ray B A, instead of the ray C A, to be brought to the axis of the eye at F. This lens must be a concave one (or at least a negative one); and its principal focus must lie at C; for then the ray B A, parallel to the axis, will be deflected so as to proceed after refraction as if it came from C, when the eye itself will bring it to F. If this lens is supposed to be placed at or in the eye, its principal focal distance is —H C, and its refracting power is $-\frac{1}{H\ C}$, which also indicates the degree of myopia $= +\frac{1}{H\ C}$.

The hypermetropic eye, again, would require a positive lens of the principal focal distance H.G; because such a lens would make the ray B A (parallel to the axis) assume the direction A G, when the eye would further deflect it so as to meet the axis at F on the retina. The refracting power of this lens would be $\frac{1}{H\ G}$, and the degree of hypermetropia, $-\frac{1}{H\ G}$.

In each case the focal distance of the lens is equal to that of the farthest point from the eye. If we substitute the general expression

R for the distances H C and H G, we have the general expression $\frac{1}{R}$ for the degree of ametropia. In other words, the degree of ametropia is expressed by the reciprocal of the distance of the farthest point.

As myopia requires a negative lens to correct it, and hypermetropia a positive lens, the uncorrected myopic eye is regarded by Donders as having a lens of the refracting power $\frac{1}{R}$ too much, and the hypermetropic eye a lens of $\frac{1}{R}$ too little. "We may therefore consider myopia M,* in reference to emmetropia, as a positive, hypermetropia H as a negative condition. Therefore, too, as the negative is included in the word hypermetropia, we need not write $H = -\frac{1}{R}$, but for the sake of simplicity we may use the expression $H = \frac{1}{R}$, as well as $M = \frac{1}{R}$" (p. 94).

In order to make use of the expressions which we have obtained, it is necessary to fix upon a unit of measurement, and upon the position of the point from which the distances P and R are to be measured. The unit employed by Donders, and now coming into general use for this purpose, is the Parisian inch =1·064 English, or thereby. The distances P and R are measured from what is termed the anterior nodal point† of the eye, situated, on an average, 6·957 millimetres behind the anterior surface of the cornea when the accomodation is not in exercise.

In speaking of the range of accommodation, we have hitherto confined our attention to what Donders terms the *absolute* range, *i. e.*, the extreme range of accommodation possessed by one of the eyes taken singly. We have now to explain the meaning of the terms *relative* and *binocular* range of accommodation.

In single vision with both eyes, the visual lines must intersect one another in a point on the surface of the object looked at. These lines, accordingly, assume different degrees of convergence according to the distance of the object; and the magnitude of the angle formed by them at their point of intersection depends on the distance of the object, and on the distance between the two eyes. The nearer the object is, the greater is the angle of convergence.

The nearer the object is, the greater, too, must be the tension of accommodation, in order that the focal adjustment of the eye may be accurate. Convergence of the visual lines and accommodation are thus associated acts; and a certain harmony must exist between the degree of convergence of the visual lines and the degree of accommodative power called into action; otherwise, we could not use both eyes together, except under the alternative of double vision or imperfect definition of the object.

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* M. and H. are contractions used by Donders to denote myopia and hypermetropia.

† The reason for fixing on this point will afterwards appear.

There are three suppositions according to which the conditions of single vision and distinct vision with both eyes might be fulfilled :—

1. Each degree of convergence of the visual lines might be associated with a certain degree of accommodation, and with that only.

2. With any degree of convergence of the visual lines, any degree of accommodation, within the absolute range, might be associated.

3. With each degree of convergence of the visual lines, a certain range of accommodation, less than the absolute range, might be so associated, that the points on which the visual lines are directed, should lie within the region* corresponding to this contracted range of accommodation. Thus, an emmetropic person with an absolute range of $\frac{1}{4}$ might, perhaps, direct his visual lines on a point 12 inches distant, and, at the same time, accommodate his eye for any point between 24 inches and 6 inches distant; or he might, perhaps, direct his visual lines on a point 8 inches distant, and, at the same time, accommodate for any distance between 16 inches and 5 inches, but not for any point outside of these limits, unless he altered the convergence of his visual lines.

The last of these three suppositions is the true one; and the *relative range of accommodation* is the range associated with each degree of convergence. It is the range which the individual possesses relatively to the angle under which the visual lines may happen to be inclined to one another. Thus, in the imaginary case given above, when the eyes are directed towards a point 12 inches distant, the *relative farthest point* is 24 inches distant, and the *relative nearest point* is 6 inches; so that the *relative range* is $\frac{1}{6}-\frac{1}{24}=\frac{1}{8}$. When the eyes are directed on a point 8 inches distant, the distance of the *relative farthest point* is 16 inches, that of the *relative nearest point* is 5 inches, and the relative range is $\frac{1}{5}-\frac{1}{16}=\frac{1}{7{\cdot}3}$.

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* Of course, in looking at objects with the naked eyes, the conditions of single and distinct vision are both fulfilled only when the eyes accommodate for a certain point in this region, viz., the point towards which the visual lines converge. By using spectacles of different powers, the eyes may accommodate for a succession of different points in their visual lines, without change in their convergence, or disturbance of vision.

The contractions used by Donders to denote these terms are as follows :—

Relative nearest point............ p_1
Its distance from the eye ...... P_1
Relative farthest point .... r_1
Its distance from the eye ...... R_1
Relative Range...... $\frac{1}{A_1}=\frac{1}{P_1}-\frac{1}{R_1}$.

The *relative range* of accommodation varies in magnitude under different degrees of convergence of the visual lines. Not only so, but the *relative region* occupies a different position with respect to the point towards which the visual lines are directed, when the distance of that point increases or diminishes. When an emmetropic person allows the visual lines to become parallel, they may be regarded as directed on a point infinitely distant. If the eyes are truly emmetropic, the relative and absolute farthest points coincide with one another, and with the point on which the visual lines are directed.* Such eyes cannot adjust themselves for convergent rays; and therefore the point of convergence of the visual lines lies at the farthest limit of the relative region of accommodation. So it is also in the case of myopic eyes, *mutatis mutandis* ; at a certain distance, finite in this case, the point of convergence of the visual lines comes to lie at the farthest limit of the relative range of accommodation. The absolute farthest point lies in this case beyond the limits of the region in which a harmony exists between the convergence of the visual lines and the accommodation. When the eyes are focally adjusted for the absolute farthest point, the visual lines intersect one another in a more distant point; and when the visual lines are directed upon the absolute farthest point, their convergence is associated with a degree of accommodative action whereby the eyes become focally adjusted for a nearer point. If the convergence of the visual lines is increased still farther, the tendency to increased associated tension of accommodation does not quite keep pace with the increase of convergence; and when the visual lines come to converge upon a point a very little nearer than the absolute farthest point, the point of convergence comes to lie at the farthest limit of the relative region of accommodation proper to the degree of convergence of the visual lines, instead of being outside of it. Hypermetropic persons, like the emmetropic, reach the farthest limit of the region, within which distinct binocular vision is possible, when the visual lines are parallel. When the farthest limit of the relative region of accommodation is the point of intersection of the visual lines, that point is termed the *binocular farthest point* (r_2).

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* A point infinitely distant from the eye.

In emmetropic, hypermetropic, and most myopic eyes, the nearer the object looked at, the nearer does the point of intersection of the visual lines approach the relative nearest point, until, at length, it coincides with it, and then the *binocular nearest point* (p_2) is reached.* This is the nearest point, the vision of which with two eyes is at once single and distinct. The eyes can accommodate focally for a somewhat nearer point—the absolute nearest point—but the degree of accommodative action necessary for this is associated with convergence of the visual lines on a much nearer point.

Thus, in the case of the emmetropic person already used as an illustration, the absolute near point is at a distance of 4 inches; but the degree of accommodative action necessary for the focal adjustment of the eye to this distance is associated with a convergence of the visual lines upon a much nearer point than the absolute near point—upon a point $2\frac{1}{2}$ inches perhaps, instead of 4 inches, from the eyes. When the visual eyes intersect in a point a little further off than 4 inches, say $4\frac{1}{4}$ inches from the eyes, it may be possible for the eyes to accommodate themselves focally for the same point. This is the *binocular nearest point.*

The distance of the *binocular farthest point* is represented by R_2, that of the *binocular nearest point* by P_2. The *binocular region* of accommodation lies between p_2 and r_2; and its extent is $R_2—P_2$. When the visual lines intersect one another in the binocular farthest point, every point in the *relative region* of accommodation is between the eyes and the point of intersection, except in hypermetropia. When they intersect in the binocular nearest point, every point in the *relative region* is beyond the point of intersection, except in some cases of extreme myopia.

The *binocular range of accommodation*, on the principles already explained, is expressed by $\frac{1}{P_2} - \frac{1}{R_2}$. The *binocular* region and range are, each of them, less than the *absolute* region and range respectively.

We may now proceed to our analysis of the work under review.

It commences with a short introduction on the conditions of accurate vision, and on the function of the retina.

* In some cases of extreme myopia, however, the relative and binocular near points do not coincide.

"In order to see an object distinctly and accurately, two conditions must be fulfilled. In the first place, an inverted, but well-defined, image of the object must be formed on the surface of the membrana Jacobi, or layer of rods and bulbs of the retina. In the second place, the local change here excited must be conveyed to the fibres of the optic nerve, communicated to the brain, and again, in an inverted direction, projected outwards"—(p. 1).

The lesions of vision, for each eye separately, are accordingly referred to three classes: *amblyopia* (including amaurosis), where the disturbance is owing to anomalies in the retina, optic nerve, or brain, and the second condition is not adequately fulfilled; *obscurities* in the media of the eye, causing clouding of the image through diffusion of light; and *anomalies of refraction and accommodation*, in which there is either no defined image of external objects produced at all, in consequence of abnormal curvature of the refracting surfaces, or the image is not formed on the layer of rods and bulbs. In the last two classes, the fulfilment of the first condition is interfered with.

"A glance with the opthalmoscope into such an eye will show whether obscurity of the light-refracting media be present or not. If such be not found, we must infer the existence of either amblyopia, or of disturbance of refraction, or of accommodation. If now, even with the aid of convex glasses, perfectly-defined vision can at no distance be obtained, the case is one of amblyopia. If, on the contrary, the power of vision be, at one distance or other, accurately defined, or if, at least, by the employment of a convex glass, a perfect definition be attainable, we have to deal with an anomaly of refraction or accommodation, opacity and amblyopia are excluded"—(p. 2).

In a note appended to this introduction, we have a short anatomical description of the retina, and a statement of the author's reasons for supposing that the layer of rods and bulbs is the part on which the picture of external objects must be defined, in order to permit of distinct vision. These we need not state here, because we presume that they are pretty generally known and assented to.

We must confess that we cannot admit the force of the following argument in page 6:—

"It is a fact, that every rod cannot have its nerve-fibre; to that end (the place occupied by a rod and nerve-fibre on section being assumed to be equal) the nerve must have a section equal to the surface of the whole retina."

The assumption made in the parenthesis is certainly not warrantable in the present state of our knowledge. Some of the nerve-fibres—and, it may be, all of their ultimate fibrilli—are much thinner than the rods.

The first chapter begins with the proofs of accommodation. These may be stated to consist in the fact, "that we are able clearly and accurately to distinguish objects at different distances," and "that we cannot *at the same time* plainly distinguish remote and proximate objects" (p. 9). This may be illustrated by such experiments as holding a veil at some inches from the eye, and a book at a somewhat greater distance; when we can accurately see either the print or the texture of the veil at will, but not both at the same time.

A change must, therefore, take place in the eye. But what is the nature of this change?

"*The change consists in an alteration of the form of the lens: above all, its anterior surface becomes more convex and approaches to the cornea*"—(p. 10).

Donders regards Thomas Young as the first who proved experimentally that the power of accommodation depends on a change of form in the lens, though others had previously entertained the idea as a hypothesis. For many years, however, Young's views were not regarded as conclusively proved.*

Means of determining the question were afforded by Purkinje's discovery of the images formed by reflection at the anterior and posterior surfaces of the crystalline lens, made in 1823; but the observation of these images does not seem to have been employed for this purpose until Maximilian Langenbeck, in the course of some experiments on the images, published in 1849, discovered "*that in accommodation for near objects the anterior surface of the lens becomes more convex*"—(Donders, p.12). Cramer and Helmholtz experimented on the same subject, taking greater precautions to insure accuracy in their results than Langenbeck had done. The former proved that the anterior surface of the lens becomes more convex and approaches the cornea; the latter showed that the posterior surface of the lens also becomes rather more curved, and satisfied himself of what Cramer had already supposed—perhaps on insufficient evidence,—viz., that the posterior pole of the lens does not materially alter its position.*

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* One of Young's experiments really was conclusive in so far as his own eyes were concerned. Although this experiment does not succeed in every case—requiring eyes of a peculiar conformation to bring out the results—the fact that Young's lens underwent changes of form during accommodation, afforded, to say the least of it, very strong presumptive evidence that the lenses of others did so too; although the same method of demonstrating it might not be applicable to their cases.

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* The curved surfaces of a refracting apparatus, such as those of the cornea and lens, reflect the incident light in such a way as to form images of objects placed in front of them. If the surface is convex, the reflected light proceeds as if it came from an erect virtual image behind it. If the surface is concave, the reflected light forms a real inverted image in front of it. In either case, if the object is a sufficiently distant one, the image is situated very nearly halfway between the reflecting surface and its centre of curvature.

By placing a luminous object (or a square hole in a screen) of known dimensions at a distance of several feet from the eye, and employing means for the measurement of its image produced by reflection at the surface of the cornea, we get the data for estimating the length of the radius of curvature of the cornea; because, size of the object : size of the image : : distance of the object : half the radius of the cornea. If we know the length of the radius of the cornea, and the index of refraction of the aqueous humour, we can, by certain observations on the iris, indirectly estimate the distance between the cornea and the anterior surface of the lens; and then we can determine the effect of refraction at the cornea in modifying the apparent size and position of the image formed by reflection from the anterior surface of the lens. When we know this, we can measure the radius of that surface as we did in the case of the cornea.

In like manner, if we can determine the effect of refraction at the cornea and at the anterior surface and in the substance of the lens (this last is a much more difficult matter), we know how far the real and apparent size and position of the image formed by reflection from the posterior surface of the lens are modified by refraction; and then we may proceed to measure its radius of curvature.

Changes in the *relative positions of the images* may be caused both by changes in the form and by changes in the position of the reflecting surfaces. Changes of the latter class are at once observed under the mode of observation pursued; for the images are seen in perspective, as it were, being viewed from the side. Changes of the former class, if unaccompanied by changes in the position of the surfaces (or rather of their apices), would, under the conditions usually observed in conducting these researches, escape direct observation; because they would take place without any change in the parallax of the images, except such as might be due to refraction. But they might be inferred from changes in the *size* of the images.

The results of experiments carefully conducted by Helmholtz, with the aid of most ingenious appliances, are as follows:—

1st. The erect image formed by reflection from the cornea does not change its size and position in accommodation: hence the curvature of the cornea remains unaltered.

2nd. The erect image formed by reflection from the anterior surface of the lens becomes smaller in accommodation, and it is seen to approach that formed by reflection from the cornea: hence the curvature of the surface becomes greater, its radius shorter, and it approaches the cornea.

3rd. The inverted image formed by reflection at the posterior surface of the

Next follows a note containing a description of instruments employed in these investigations; viz., one which Cramer termed an *ophthalmoscope*, which has been modified by Donders, and renamed *phacoidoscope*,* and the ophthalmometer of Helmholtz, an instrument which is in some respects a more ingenious invention than his *ophthalmoscope.*

The next section is upon the *mechanism of accommodation.* Our author arrives, by exclusion, at the opinion that the ciliary muscle is the organ of accommodation.

In accordance with this view, he describes the theories of Helmholtz and H. Müller with regard to the *modus operandi* of the ciliary muscle in effecting the accommodative change. According to Helmholtz, the contraction of the ciliary muscle relieves the lens from a tension exerted upon it by the zonula Zinnii, which, in its turn, is kept on the stretch by the pressure of the vitreous humour. The lens, thus relieved, becomes thicker, in virtue of its natural elasticity. According to H. Müller, the lens is rendered thicker in consequence of having its margin pressed upon by the contraction of the circular fibres, which he describes as forming a separate portion of the ciliary muscle. Circumstances are adduced by both writers to explain certain difficulties which present themselves, such as the fact that the increased convexity of the lens is mainly confined to its anterior surface, the question as to what becomes of the aqueous humour when the anterior chamber diminishes in depth, &c. Into these subsidiary details we cannot enter here. In some respects the two theories agree with one another, in others they differ. Donders states that he sees difficulties in the way of adopting either view.

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lens (which is *concave anteriorly*) becomes a very little smaller in accommodation for near objects : hence the posterior surface of the lens becomes more curved, and its radius becomes shorter. It seems that little or no change can be detected in the *position* of this image on accommodation for near objects. If we leave out of account the effect of refraction on the light entering the eye and returning from it after reflection at the posterior surface of the lens (and Helmholtz states that, in consequence of accidental compensations, this influence scarcely affects the matter at all), there must be some change in the real, though not necessarily in the apparent, position of the image—a change due to the increased curvature of the surface, even if the posterior pole of the lens remains in the same position as formerly.

* The name "ophthalmoscope" has since been applied to the speculum oculi invented by Helmholtz, and is universally used in this sense. The term "phacoidoscope" is more appropriate to the purposes for which the instruments of Cramer and Donders are suitable.

Mackenzie, in his "Physiology of Vision" (London, 1841), states a circumstance which seems to have a bearing on the subject more favourable to the view of Helmholtz than to that of Müller, although it is brought forward in connection with an hypothesis different from and not so fully worked out as either of theirs. He says—

"In a short paper which I published on this subject, in 1834, I stated that we had little more than one fact, established by observation, regarding the question of adjustment; viz., the contraction of the pupil when near objects are viewed, and its expansion when the eye was directed to objects at a distance, as was readily ascertained by inspecting the healthy eye in any living individual; but that I had observed in the dead eye another fact which seemed to bear upon the question.

"After death the pupil generally presents a medium size, but in some eyes we find it small, and in others large. In those eyes in which we find the pupil small or contracted, we find the ciliary circle expanded, so as to be separated a considerable way from the lens; but in those eyes in which the pupil is large or dilated, we find the ciliary circle contracted round the edge of the lens, or even intruding on the anterior surface of the capsule.

* * * * * * *

"The hypothesis, then, which I have formed is, that the pupil and the ciliary ring are antagonists; so that, while the pupil contracts on our directing our attention to near objects, the ciliary circle expands; and when we look at distant objects, the pupil expands and the ciliary circle contracts around the lens"—(pp. 185, 186).

He conjectures that as the ciliary circle expands, the lens may be permitted to advance, but that by its contraction the lens is made to retire, and that these changes of position may be accompanied by changes of form in the lens, its axis becoming longer in the first and shorter in the second instance. It is to the observation, however, and not to the hypothesis, that we desire to direct attention.

Donders mentions that in a case described by von Gräfe, in which the power of accommodation remained after the loss of the iris, the ciliary processes, which were visible, were not observed to be displaced in accommodation for near objects.

There is a long and elaborate note appended to this chapter, extending to forty-two pages, and containing, 1st, an account of the dioptrics of the eye, and 2ndly, discussions connected with the range of accommodation, both being treated mathematically.

It is true that the reader of this note will find nothing in it which he cannot master, if he is acquainted with the simple rules of algebra, and with a very limited portion of the first book of Euclid; but the calculations are rather difficult to follow, in consequence of the number of letters introduced into the formulæ, and the number of terms expressed by the same letter, embellished, for the sake of distinction, by numbers, dashes, and double dashes in every variety of combination.

We are well aware that it is difficult to avoid this in such demonstrations; but an oculist like Donders ought to consider the effect which the study of his equations is likely to produce upon the eyes of the medical public, all unused to such tasks; and we can picture to ourselves how a conscientious reader, with spectral images of f'''s and f''''s, F_2'''s and F_1''''s, k's and h's, β's and γ's, ϕ's and δ's; with one dash, with two dashes, and without dashes; double dashes coalescing and forming single dashes, single dashes splitting up into double dashes; j's confounding themselves with f's, and k's confounding themselves with h's, all dancing before him, and with a confusion of ideas proportioned to the confusion of vision, and quite disproportioned to the intrinsic difficulties of the subject—might revert to the beginning of the note, and reading there the announcement of its simplicity,* might conceive the author to have penned his words in a spirit of the bitterest irony. We think, too, that some of the conclusions might have been arrived at by less circuitous and complicated processes; but, bating these blemishes, the note is really an admirable one, and well worthy of careful perusal.

At page 39, near the commencement of this note, Donders comments on the fact, that, in consequence of its graduated density, the crystalline lens has a shorter focal distance than it would have, even if its whole mass had as high an index of refraction as the nucleus has. He refers to Young as having been the first to call attention to this fact; but he states that "for a long time physiologists assumed an index, the mean of that of the nucleus and that of the periphery;" and that Senff, having subsequently made the same observation which Young had made before him, generally got the credit of it. Others, however, between Young and Senff (whose observations, referred to at p. 39, appeared, we believe, in 1846), drew attention to the matter. Thus Herschel (Phil. Trans. for 1821, p. 233) alludes to Young's observation, and makes the properties of such lenses a subject of mathematical investigation. Mackenzie also (Physiology of Vision, published in 1841, p. 87) states Young's view on this point, and gives a very intelligible popular illustration of it.

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* See page 38, line 15.

Of course we cannot undertake a complete analysis of this portion of the work, and we shall, therefore, content ourselves with a brief explanation of the more important particulars contained in the first part of it, reserving the second part to be taken up along with the section to which it refers.

Our author makes the following statement (p. 39):—"Optical mathematicians seek, namely, for a given system of refracting surfaces, certain fixed points, called *cardinal points;* and the knowledge of these is sufficient to enable us to construct and calculate the situation and size of the images of given objects. The conditions are:—1st, that the system be centred, that is, that the centres of curvature of all the refracting surfaces lie in a right line, the axis of the system; 2ndly, that the rays intersect the axis at only small angles. The first condition appears to be amply fulfilled by the structure of the eye, as the second is by direct vision, that is, by looking nearly in the direction of the line of vision."

We shall accordingly give a brief description of the cardinal points of centred dioptric systems consisting of one or more spherical refracting surfaces.[*] These are, two *nodal points,* two *principal points,* and two *principal foci.*

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[*] This is the more necessary, because we believe that some English readers may not be familiar with one or two of the terms employed by foreign writers on physiological optics; such as "nodal point" (Knotenpunkt), a term first applied in the sense in which we shall employ it by Listing, to whom, in great measure, we owe the definite character attaching to recent observations on the optics of vision. The refracting surfaces of the eye are not spherical; but this does not affect the matter in so far as it concerns conclusions with regard to conjugate focal distances, &c., when the incident rays form moderate angles with the axis of the system. The peculiar forms of the surfaces, indeed, are probably such as to diminish the aberrations which might result from their being all of a spherical, or, it may be, of any one form.

In the catoptric investigations conducted by Helmholtz and others, with the view of ascertaining the radii of curvature of the refracting surfaces, the experiments were so performed that the reflected light, which ultimately reached the eye of the observer, was reflected, as nearly as possible, from the apex of the surface under investigation; and the length of radius ascertained corresponded to the radius of curvature of an infinitesimal portion of the surface at that point. The same conditions of observation also insured (so far as was practicable under the circumstance of possible non-coincidence of the axes of the various surfaces) that the light, if refracted, should undergo equal refractions before and after reflection; thus eliminating certain of the disturbances due to refraction.

Nodal Points.—The first and second *nodal points* of a dioptric system are two points situated in its axis, and they have this peculiarity, that if the line of direction pursued by a ray before its first refraction passes through the first nodal point, the line of its direction after the last refraction passes through the second nodal point, and its ultimate line of direction is parallel to its original one.*

The *principal planes* † are two planes which intersect the axis at right angles, and they have this peculiarity, that if a ray, before its first refraction, is directed towards a point in the first principal plane, its direction line, after the last refraction, will, if traced backwards, intersect the second principal plane in another point; and these two points in the principal planes are equidistant from the axis, and on the same side of it.

Principal Points.—The first and second principal points are the points in which the axis cuts the first and second principal planes, respectively.

If the line of direction of a ray coincides with the axis of the system, that ray passes through it unrefracted.

When there is only one refracting surface, the two nodal points coincide with one another, and with the centre of curvature of the surface. Any ray which is directed towards this point before it meets the refracting surface, proceeds unrefracted, and actually passes through the point towards which it was originally directed. In this case, the principal points coincide with one another, and with the point (termed the *apex*) where the axis cuts the refracting surface. Thus, a single spherical refracting surface has but one nodal point and but one principal point.

If the system consists of two or more spherical refracting surfaces, and if the centres of curvature of the surfaces coincide with one another, the nodal points coincide with one another and with the centre of curvature. Any ray directed towards this point passes on unrefracted.

With the exceptions mentioned above, any ray which passes through a dioptric system, such as those of which we are treating, is refracted once or oftener before it emerges.

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* This does not mean that the ray itself actually passes through the nodal points, but that its lines of direction in the first and last media would, if traced forwards or backwards, intersect the axis in the first and second nodal points respectively.

† It is necessary to describe these here, because an idea of their nature is essential to a right conception of what is meant by the *principal points*. They are not, properly speaking, *planes*, but imaginary *curved surfaces*; however, for all ordinary purposes, we may regard them as planes.

When the first and last media (those bounding the system) have the same refracting power, the anterior nodal point coincides with the anterior principal point, and the posterior nodal point coincides with the posterior principal point. When the first and last media are of different refracting power, the nodal points do not coincide with the principal points.

Principal Foci.—The principal foci are two points situated in the axis. Rays whose lines of direction before the first refraction pass through the first principal focus, proceed parallel to the axis, after passing through the last surface. If rays proceed parallel to the axis before the first refraction, their lines of direction after refraction pass through the second principal focus.

Principal Focal Distances.—According to the system pursued by the German writers, whom Donders follows, the distance between the first principal point and the first principal focus is termed the first principal focal distance; and it is regarded as positive when the first principal point lies behind the first principal focus,* and negative, when, as in concave lenses, the first principal focus is behind the first nodal point. The distance between the second principal point and the second principal focus is termed the second principal focal distance; and it is considered positive when the second principal focus lies behind the second principal point; negative, when it lies in front of it.

The distance of the *first nodal point* from the *first principal focus* is equal to that between the *second principal point* and the *second principal focus*, or the *second principal focal distance;* and the distance of the *second nodal point* from the *second principal focus* is equal to the *first principal focal distance.* Hence, the distance between the first nodal and first principal point, and the distance between the second nodal and second principal point, are each equal to the difference between the two principal focal distances; and the distance between the two principal points is equal to the distance between the two nodal points. The first and second principal focal distances, as measured from the first and second principal points, are proportional to the indices of refraction of the first and last media respectively. In common lenses placed in air, the two principal focal distances are equal to one another.†

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* That is, in the direction towards which the light is going. Thus, if the light is proceeding from left to right, a point to the right is regarded as *behind* a point situated to the left of it.

† We state these optical facts here, because we believe that this summary of

When the position of the cardinal points is known, we can calculate the distances of conjugate foci, either from the nodal or from the principal points, by means of simple formulæ.

Optical Centre.—In ordinary biconvex and biconcave lenses, and in the human eye, the nodal points are so close to one another that we may generally regard them as one, or take a certain intermediate point as their single representative. This point is termed the *optical centre.* It is situated in the axis, between the nodal points ; and it has this property, that if the direction lines followed by a ray in the first and last media pass through the first and second nodal points respectively, the ray itself actually passes through the optical centre.*

As the principal and nodal points coincide with one another in lenses bounded by air on either side, the optical centre represents the principal, as well as the nodal, points ; and it is customary to measure the focal distances from it. In the human eye, the first and last media—air and vitreous humour—are of different refracting power ; and therefore the principal and nodal points do not coincide with one another. Hence the optical centre does not represent the principal points; but there is a point between them which has this property, that if the direction-lines, pursued by a ray in the first and last media pass through the first and second principal points respectively, the ray itself actually passes through that intermediate point; and we may take it as the representative of the principal points, and measure focal distances from it.

The distance of the optical centre is a little more than 7 mm., and that of the single principal point is a little more than 2 mm., from the anterior surface of the cornea. The anterior principal focal distance is about 15 mm., and the posterior focal distance is about 20 mm.†

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them may be found useful for purposes of reference by readers of Donders. Those who read German will find a very clear exposition of the subject, of which we have availed ourselves, at pp. 38, 39, 40, of Helmholtz's article, "Physiologische Optik," in Karsten's "Allgemeine Encyklopädie der Physik"—Leipzig, 1856.

* This description, however, does not apply to the case of all lenses and systems. In certain lenses and systems (the meniscus for example), the nodal points lie outside of the bounding surfaces, the optical centre does not lie between the nodal points, and a ray whose lines of direction in the first and last media intersect the axis in the nodal points, does not actually pass through the optical centre, though its line of direction while it is passing through the glass is directed towards that point.

† These measurements express in round numbers the distances in an average emmetropic eye during rest of accommodation.

Let F' = the anterior principal focal distance.

F'' = the posterior do. do. do.

G' = the distance between the anterior nodal point and the anterior principal focus.

G'' = the distance between the posterior nodal point and the posterior principal focus.

f' = the known distance of a luminous point from the anterior principal point.

g' = the known distance of the same luminous point from the anterior nodal point.

f'' = the distance of the focus conjugate with the luminous point from the anterior nodal point.

g'' = the distance of the same conjugate focus from the posterior nodal point.

Then we have $G'=F''$, and $G''=F'$; and the following are the formulæ for calculating the distance of the conjugate focus from the posterior principal point, and from the posterior nodal point, respectively :—

$$f''=\frac{f'F''}{f'-F'}\text{; and } g''=\frac{G''g'}{g'-G'}.\text{*}$$

In the remarks on refraction at a single spherical surface, we were surprised to find the following statement :—

"The points of an object, which lie in a line perpedicular to the axis, are also in the image situated in a line perpendicular to the axis"—(p. 42).

By this he evidently means, as may be seen on reading his demonstration,—a *straight* line perpendicular to the axis, and not a curved line crossing the axis at right angles. But the image lies in a curved, and not in a straight line, as Donders asserts; and his assertion involves this: that the focus conjugate with a point nearer the optical centre is also nearer the optical centre than that corresponding to a more distant point, provided that the former point is situated in what we regard as the axis of the surface, and that the latter is not in this axis; all which is erroneous.

This is a curious instance of inadvertently stating as a fact what really rests on a conventional assumption. And, not content with his assertion, he proceeds to give an elaborate proof of it, which would be all well enough if the diagram (fig. 19)† could be depended upon in every respect. If the object has any appreciable magnitude, the image of i' will not lie in j', because the ray $i'b$ does not pass through ϕ'' after refraction, in "every value of hb or ii'; but, as soon as ii' ceases to be practically infinitesimal, the refracted ray bj' comes to cut the axis in a point nearer k than ϕ'' is, and the farther from ϕ'' the greater the distance ii'. The whole argument to prove the assertion quoted above, is based on the supposition that the ray bj' does cut the axis in ϕ''. Thus, what Donders alleges as a fact, and proves from the diagram, is indirectly assumed in the diagram, and is made use of in either case to facilitate the finding of formulæ for calculating conjugate focal distances, and the exposition of the relation between the magnitude of an object and that of its optical image. As a mere assumption, it may be legitimately used in this way; for it introduces no error into the former result, as Donders works it out, in consequence of incidental compensations; nor yet into the latter, as long as the object subtends, at the optical centre, an angle so moderate that the arc and the tangent may be regarded as equal to one another; for the image subtends a similar angle at the optical centre, and in most cases very nearly coincides with the arc, the tangent to which represents the image in the diagram. The diagram, fig. 19, is the same in principle with one used by Helmholtz* to show the method of finding the position of the optical image (or conjugate focus) of a point not in the axis. As employed by him, it is simple and ingenious. Like most optical diagrams, it involves assumptions, and even conclusions, not strictly true, except for infinitesimal quantities; but these are of such a nature that they do not affect the general truth of the results, when they are rightly understood and applied.

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* See pp. 43, 44 of Donders.

† See p. 43 of Donders.

We now come to the section on the *range of accommodation.* This precedes the optical note to which we have already referred; but we have found it expedient to postpone the consideration of it till now, and to take it up, together with that portion of the note which relates to it.

In introducing this subject, Donders states that, "In all the investigations respecting the cause and mechanism of accommodation, observers appear not to have thought of defining the range of accommodation under various circumstances, and of seeking a simple numerical expression for the same" (p. 28); but, at page 109, he says:—"The idea of expressing the range of accommodation by a lens of definite focal distance is to be met with so early as in the masterly work of Young (*Philosophical Transactions*, 1801)."

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* "Physiol. Optik," in Karsten's Encyklopädie, p. 41, fig. 25.

He then gives his formula $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$ which we have already expounded; $\frac{1}{A}$ expressing the refracting power, and A the focal distance of the lens, equivalent to the range of accommodation.

The distances P and R are measured from the *anterior nodal point* of the eye, which is situated about three Paris lines behind the anterior surface of the cornea; and Donders accordingly proceeds to describe the nodal points, and to state their importance.

A ray, whose original and ultimate lines of direction pass through the nodal points, will, if it comes from a point of an object for which the eye is focally adjusted, proceed, like the other rays which have the same point of origin, to the point in the retinal image corresponding to that point in the object; and if we know the magnitude and distance of the object, the position of the nodal points, and the distance between them and the retina, we can calculate the size of the retinal image. The original and ultimate directions followed by such a ray are parallel to one another. Hence the angle formed at the anterior nodal point, by straight lines drawn to it from the extremities of the object, is equal to that formed at the posterior nodal point by straight lines drawn to it from the extremities of the retinal image. From this it follows that the magnitude of the image is to that of the object as the distance of the image from the posterior nodal point is to the distance of the object from the anterior nodal point.

As the nodal points of the eye are very close together, the direction-rays above mentioned, whose inclination determines the magnitude of the retinal image, are often regarded as passing unrefracted through the optical centre. This simplifies the matter, as the distances of the object and image are measured from one and the same point. The error thus introduced is very slight; but it may be still further reduced by substituting the posterior nodal point for the optical centre, when the object is considerably more than ½ inch in front of the cornea. In any case, the posterior nodal point is the point of decussation of the lines of visible direction. In strict accuracy, however, the distance of the image should be measured from the posterior, and that of the object from the anterior nodal point.

Donders does not categorically state his reason for fixing on the *anterior nodal point*, as the starting-point for the measurement of P and R. This is rather to be regretted, because one might suppose that the *anterior principal point* would be more suitably chosen in some respects; for, in recent works on physiological optics, focal distances are usually measured from the principal points of a dioptric system, and they are so measured in some of the mathematical parts of this work. Besides this, the formula $\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$ would, if applied according to this system of computation, afford a more direct and accurate expression of the practical value of the accommodative change—of the change in the refracting power of the eye, as exemplified in the increased deflection of incident rays,—than it does when used as it is by Donders.

Nevertheless, there are good practical reasons for adopting his system, much more important than the theoretical one we have mentioned. Focal distances can be calculated from the nodal as well as from the principal points. Questions of focal distance are often complicated in practice with questions relating to the magnitude of retinal images. Not only are imaginary lenses employed to express ranges of accommodation and degrees of ametropia, but real lenses are used in practice to ascertain them. These indirectly affect the magnitude of the retinal images; and this, again, more directly depends on the position of the nodal points in the eye. Thus, there is no need of introducing two systems of measurement into our calculations; and all the less, when we consider that the distance (about 5 mm.) between the anterior nodal point and the anterior principal point is a mere trifle in comparison with the distances P and R in most cases. It must be remembered, too, that the positions of the nodal and principal points in the eye change as the accommodative change takes place. Therefore, strictly speaking, the addition of an infinitesimally thin lens, real or imaginary, even if its nodal or its principal point coincided with the anterior nodal point of the eye in rest of accommodation, would not, in all respects, represent the change which takes place in accommodation.

In practically determining the range of accommodation, it is necessary, in the first place, to ascertain exactly the position of the point r "with a nearly parallel state of the lines of vision, that is, by fixing with both eyes an object at least 5 mètres * distant. We know, namely, that when the lines of vision converge, accommodation necessarily takes place, and that consequently the true farthest point in total relaxation of accommodation cannot thus be found. As an object, we may use groups of vertical black lines, each line $2\frac{1}{2}$ millimètres thick and 10 millimètres from one another, and examine whether they can at the distance of 5 mètres be seen with perfect accuracy with the naked eye, or whether the sharpness of the object can be increased by glasses. If no improvement is attainable by glasses, r lies at least 5 mètres distant, which may here be equally represented by an infinite distance ∞. Where near-sightedness exists, concave glasses, with negative focal distance, are required to attain perfect accuracy: in this case we determine what is the weakest glass of this nature with which the sharpest possible vision is obtained"—(pp. 31, 32). We may mention here, though Donders does not enter into the question in this section, that the degree of hypermetropia is determined by trying what are the strongest convex glasses with which accurate vision of the distant object is obtained. If we wish to bring out the total amount of hypermetropia, we must paralyse the accommodation by instillation of a solution of atropine, and determine the position of p before the instillation, or after its effects have completely passed off.

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* Between 16 and 17 English feet.

The refracting power of the lens required is not exactly $\frac{1}{R}$, nor is its principal focal distance $= R$; because, though a lens could be devised which, when placed in air, might have its second nodal point coincident with the anterior nodal point of the eye, such lenses would be faulty in other respects; and we therefore use lenses whose optical centre lies in the substance of the glass. These lenses are generally placed about $\frac{1}{2}$ inch in front of the anterior nodal point of the eye. If the eye is myopic, the point r is situated at one of the principal foci of the lens,* for the object of employing it is to make parallel rays diverge, as if they came from r, and the distance between the lens and r is equal to the principal focal distance of the former, which we may represent by F. But F is evidently half an inch less than R, which is the distance between the anterior nodal point of the eye and the point r. Hence, if we express this half-inch, or whatever it may be, by x, we have $R = F + x$; and F and x being known quantities, we know what R is.

"Let us illustrate this by an example. A near-sighted eye, to see accurately at a distance, needs a glass of 15 Parisian inches negative focal distance ($F=15$), placed at a quarter of an inch in front of the cornea, that is, half an inch before the nodal point k' in the eye ($x=\frac{1}{2}$); then $R=F+x=15\frac{1}{2}$ Parisian inches"—(p. 32).

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* The second principal focus, which is here in front of the lens.

If the eye is hypermetropic, r is situated behind it at the second principal focus of the convex correcting lens; for the lens must make parallel rays converge towards this point. The distance F (which we may suppose $=15$, x being$=\frac{1}{2}$), is, in this case, half an inch longer than r. Hence $R=F-x=15-\frac{1}{2}=14\frac{1}{2}$.

Donders states, that in determining the nearest point (p), "Theoretically we should, in order to be able to institute a comparison, always determine the nearest point at the same angle of convergence, as the farthest point is examined with parallel lines of vision. This would, however, be attended with great practical difficulties, and, as I shall hereafter show, would, moreover, lead to wholly incorrect results. The only thing required in this respect is, that in all the cases where the nearest point lies farther from the eye than 8″,* the determination should be made with the use of such convex glasses, that the nearest point should be brought to about 8″ from the eye" —(p. 35).

When we have got the proper glasses, the focal distance (F) of which we know, and when we have found the distance (P″) between the lens and this reduced nearest point, we may find the distance (P′) between the lens and the real nearest point by the following formula :—

$$\frac{1}{P'}=\frac{1}{P''}-\frac{1}{F}.$$

"The distance P of the nearest point is $=P'+x$. An example will illustrate this. With a lens of 12″ focal distance ($F=12$), removed $\frac{1}{2}$″ from k' ($x=\frac{1}{2}$), the point p',† situated $7\frac{1}{2}$″ from the lens, is accurately seen. We therefore find the distance P′ from

$$\frac{1}{7\frac{1}{2}}-\frac{1}{12}=\frac{1}{20}$$

to be 20″ from the eye,‡ and P is therefore 20·5 inches"—(p. 36).

In determining the distance R, in place of vertical black lines, letters, such as Snellen's,|| may be placed at a distance of 20 feet from the patient, and employed as tests of the accuracy of his focal adjustment. In determining the distance P, a wire optometer, described in the text, is used as test-object. Small print may be similarly employed in order to check the results obtained.

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* 8 Parisian inches.

† He refers here to a diagram.

‡ This should be "20 from the *lens*."

|| The letters given at page 33, as corresponding to XX of Snellen, are really much larger; but the interspaces between the strokes of which they are composed are, perhaps, not wider than those in XX.

Donders describes a simple and graphic method of "expressing the *ranges of accommodation* by the *lengths of lines*, which exhibits, at the same time, the commencement and termination of the range of accommodation, that is the nearest and farthest points of distinct vision. Above parallel lines, situated at equal distances from each other (Fig. 16),* let numbers be placed, expressing the distances of distinct vision, and in such an order, that the distance between two lines may everywhere represent an equal range of accommodation, for example, $\frac{1}{24}$"—(p. 36).

If we number these lines thus: ∞, 24, 12, 8, &c., "the differences of the distances from line to line always amount to $\frac{1}{24}$ of the range of accommodation;† this is true from ∞ to 24, from 24 to 12, from 12 to 8, &c.; for

$$\frac{1}{24}-\frac{1}{\infty}=\frac{1}{24}$$
$$\frac{1}{12}-\frac{1}{24}=\frac{1}{24}$$
$$\frac{1}{8}-\frac{1}{12}=\frac{1}{24}$$

&c. A single horizontal line now immediately shows the extent and range of accommodation"‡—(pp. 36, 37).

If the horizontal line extends from the vertical line marked ∞, across the intervening vertical lines, to that marked 4, it indicates that the region of accommodation extends from infinity to 4 inches in front of the eye; and as it covers 6 spaces, each equivalent to $\frac{1}{24}$, it indicates a range of $\frac{6}{24}=\frac{1}{4}$. If, again, the horizontal line extends from the vertical one marked 6 to that marked 3, it indicates that the farthest point is 6 inches from the eye, and the nearest point 3 inches.

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* These lines are vertical in this diagram, and in the one at page 90.

† Or rather, to a portion of the range of accommodation expressed numerically by the fraction $\frac{1}{24}$. That is, to an accommodative change equal in degree to that which takes place when the eye, from being adjusted for parallel rays, accommodates for a distance of 24 inches.

‡ If we wish to number the lines, we may follow this process: $\frac{1}{\infty}+\frac{1}{24}=\frac{1}{24}$. When the numerator is 1, the denominator expresses the number required, = 24 inches in this case. $\frac{1}{24}+\frac{1}{24}=\frac{1}{12}$; No. required, 12; $\frac{1}{12}+\frac{1}{24}=\frac{1}{8}$; No. required, 8; $\frac{1}{8}+\frac{1}{24}=\frac{1}{6}$; No. required, 6; and so on. If the numerator is not unity, the fraction must be reduced to one having that numerator, or the denominator will not express the number required. Thus: $\frac{1}{6}+\frac{1}{24}=\frac{5}{24}=\frac{1}{4\frac{4}{5}}$; No. required, $4\frac{4}{5}$. The number required is the reciprocal of the fraction from which it is to be obtained; and perhaps the simplest way in such cases is to invert the fraction. Thus: $\frac{1}{6}+\frac{1}{24}=\frac{4}{24}+\frac{1}{24}=\frac{5}{24}$; No. required, $\frac{24}{5}=4\frac{4}{5}$.

It covers four interspaces between the vertical lines, and therefore indicates a range of $\frac{4}{24}=\frac{1}{6}$.

The range in hypermetropic cases may be similarly represented, if we add a series of vertical lines marked $-24, -12$, &c., in succession, and placed on the other side of the line marked ∞. A horizontal line, extending from the vertical line marked -12 through the line marked ∞, and on to that marked 12, would now indicate that the farthest point is 12 inches behind the eye, and the nearest point 12 inches in front of it; while the range of accommodation is $\frac{4}{24}=\frac{1}{6}$. This is shown in a diagram at p. 90, where, however, the vertical lines are not marked by the numbers ∞, 24, 12, &c., but by their reciprocals $\frac{1}{\infty}$, $\frac{1}{24}$, &c., directly expressing portions of the range of accommodation.

In that portion of the mathematical note already referred to, which is devoted to the range of accommodation, we find among other topics, "*a comparison of the obtained formula* $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$ *with the results of observation*"—(p. 75). The range of accommodation might be represented by an infinitesimally thin auxiliary lens, placed in air, and having its nodal point in the anterior nodal point of the eye in rest of accommodation, and its focal distance (measured from its nodal point*) $=A$; or by an infinitesimally thin lens placed in the vitreous, and having its nodal point in the posterior nodal point of the eye; but its focal distance must be less than A, and its refracting power greater than $\frac{1}{A}$. Again, the change which occurs in accommodation for near objects might be represented as mainly consisting in the addition of a positive meniscus to the front of the crystalline;† and this meniscus has a different focal distance from either of the foregoing, and its addition alters the position of the cardinal points of the eye. It so happens, that in four cases examined by Knapp, an infinitely thin auxiliary lens, placed 2 mm. behind the cornea,‡ "almost exactly corresponds to the alteration of refraction of the lens"—(p. 79). That is to say, in each case, an auxiliary lens of a calculable focal distance would, if so placed, produce the same optical effects (including changes in the position of the cardinal points) as the accommodative change in the crystalline did; but Donders considers this to be an accidental coincidence; and the application of a method founded on it would involve practical trouble and difficulty.

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* The principal and nodal point would coincide in this lens, and would lie outside of its substance.

† Examinations conducted by Dr. Knapp with the ophthalmometer and optometer, in which measurements of the changes in the refracting surfaces were compared with the actual range of accommodation, have afforded a most interesting corroboration of the view, that the change in accommodation is confined to those changes in the crystalline lens which we have already described.

‡ Between the principal points of the eye.

The question comes to be, can we establish anything like a definite relation between the addition which the crystalline receives in its refracting power and the refracting power of the imaginary lens in air?

From a comparison of actual ranges of accommodation with measurements of the changes which took place in the crystalline,—

"It appears that no perfect proportion exists between the calculated auxiliary lens, corresponding to our formula of the range of accommodation, and the actual alteration of the crystalline lens, but that nevertheless we come sufficiently near the truth in assuming that the crystalline lens in accommodation has received the addition of a lens, having $\frac{9}{10}$ of the power of $\frac{1}{A}$, the focal distance of which consequently amounts to $\frac{10}{9}$ A. This result is not without importance. The formula $\frac{1}{P}-\frac{1}{R}=\frac{1}{A}$ thus becomes more than a mathematical fiction, it acquires a physiological signification"—(p. 77).

"If we wish to know what auxiliary lens has been applied to the crystalline, we multiply the result obtained $\frac{1}{A}$ by the coëfficient 0·9. We thus come certainly very near the truth"—(p. 79).

But, for all practical purposes, we may take $\frac{1}{A}=\frac{1}{P}-\frac{1}{R}$ as the numerical expression for the range of accommodation.

(*To be continued.*)

BOOKS RECEIVED.

Mathijsen's Gipsverband en zijne laatste Wijzigingen, medegedeeld door Dr. W. Kroll. Utrecht, 1863 ; pp. 55.

Mathijsen's Plaster of Paris Bandage and its most recent Modifications. By Dr. W. Kroll. Utrecht, 1863 ; pp. 55.

Canada Lancet for September 15th, 1864.

Ueber eine eigenthümliche Erkrankung der Retina. Von Dr. A. Nagel in Tübingen.

On a Peculiar Disease of the Retina. By Dr. A. Nagel of Tübingen. (Reprint from the Centralblatt f. d. med. Wissensch. 1864. No. 45.)

Clinical Lectures and Reports by the Medical and Surgical Staff of the London Hospital. Vol. I., 1864. London, 1864 ; pp. 517.

An Inquiry into the Action and Uses of Atropia. By Alex. Fleming, M.D., F.R.C.P. Lond., Physician to the Queen's Hospital, and Consulting Physician to the Midland Eye and Ear Hospital, Birmingham. Pp. 5. (Reprinted from the *Edinburgh Journal*, March, 1863.)

Dublin Medical Press for November.

American Journal of the Medical Sciences for October.

Boston Medical and Surgical Journal, Vol. LXXI. Nos. 7 to 14. (Nos. 1, 2, 5, and 6 not yet received).

Buffalo Medical and Surgical Journal for August and September.

Australian Medical Journal for September.

Annales d'Oculistique for September and October.

Klinische Monatsblätter für Augenheilkunde for July and August.

Zeitschrift für rationelle Medicin, Vol. XXIII., parts 1 and 2.

On Long, Short, and Weak Sight, and their Treatment by the Scientific Use of Spectacles. By J. Soelberg Wells, Ophthalmic Surgeon to, and Lecturer on Ophthalmic Surgery at, the Middlesex Hospital. Second Edition. London : John Churchill and Sons. 1864 ; pp. 214.

NOTICES TO CORRESPONDENTS.

Professor Donders is thanked for the valuable series of reports and theses of the Utrecht School of Ophthalmology.

To the Editors of the Ophthalmic Review.

GENTLEMEN,—I was pleased to observe in your esteemed periodical (No. II. p. 212) that Dr. Mackenzie considered my slight little essay on the form of the edge of cataract-knives worthy of some notice; but I cannot agree with all he says, and beg of you, therefore, to find a place in your valuable pages for the following remarks, should you consider them worthy of insertion. I will be as brief as possible.

To avoid any possible misunderstanding, I may first observe, that I do not imagine that I am recommending a *new* form of cataract-knife. I am perfectly aware that knives with convex cutting-edges have been recommended by many older and modern ophthalmic surgeons. All I wished to do was to more clearly explain the difference of action between a *convex* and a *straight* edge.

Dr. Mackenzie's assertion of the great similarity of form between the knife I recommend and that of Wenzel appears to me incorrect. Admitting that in the figures the edge appears slightly convex, I still find in Wenzel's own description (Traité de la Cataracte, p. 49) the following passage:—"Cet instrument, qu'on peut nommer cératotome, ressemble à une lancette à saigner; mais sa lame a un peu moins de largeur et un peu plus de longueur; elle est *droite*, et, si quelquefois elle présente une convexité presqu' imperceptible, cela dépend uniquement de l'ouvrier." It hence follows that Wenzel recommends the very form of edge which I have designated as the *less advisable one.*

The further statement, which has unfortunately been repeated by many, that G. A. Richter took his form of cataract-knife from Wenzel, would be difficult of proof. All that I can absolutely see is, that Wenzel (the son), with an unmistakeable animus, throws this in the teeth of Richter. Even if Richter (as far as we know) accepted this without answering it, or left it completely unnoticed, it certainly cannot hence be inferred either that he considered he deserved such a reproach, or that he actually did deserve it. Every unprejudiced and impartial reader, however, who compares the descriptions of the two knives must concede :—

1. That the two descriptions are by no means applicable to one and the same form of knife (which, by the bye, Wenzel did maintain), and that Richter's knife must have been different to Wenzel's.

2. That Richter's description (*l. c.*) enters far more clearly and accurately into all the important and essential points. As we remarked,* he, "as it were, from the operation itself, mathematically deduced the construction of the best instrument for the purpose," whilst Wenzel simply enumerates the properties and dimensions of his father's knife, without going into the question of *why* it should possess these and not any other properties or dimensions. He at the same time observes, the inventor of the knife ought certainly to know more about his own knife than one who has only imitated it (he means here A. G. Richter), and, indeed, has in some particulars not even imitated it *correctly*.

We may hence, I think, infer,—

1. Richter did not borrow the form of his knife from Wenzel. I must again freely admit that Richter's and Wenzel's *figures* appear very similar ; but it has been already remarked from another quarter (Himly), that Richter's figure does not agree well with his own description ; Richter's figure is, therefore, erroneous. The figure is said to agree perfectly with the description in an English translation (which, however, I have never seen) of Richter's work.

2. Richter was far too well informed to be considered, even unwittingly, as a mere imitator of Wenzel.

I by no means underrate Wenzel's merits, and am perfectly aware that he knew things which have now and then been brought forward in the present day as novelties. I only regret to see two men, who have done so much for ophthalmic surgery, as Wenzel and Richter, quarrelling about so insignificant a question of priority. But I nevertheless consider it unjust that he who did not contribute to the propagation of this distasteful quarrel (namely Richter) should, on the simple accusation of his opponent, be stigmatized as an imitator, or even as a plagiarist.

Dr. Mackenzie's third and last statement is founded on a misunderstanding which only requires a more lucid and precise mode of expression to be cleared up. La Faye's knife was curved on the flat, and so was Casaamata's; each, however, in different directions. A *longitudinal* section of La Faye's knife, a *transverse* one of Casaamata's, would represent a slightly curved line. The latter is curved from side to side, the former from point to heel. The two are, therefore, very essentially different.

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* OPHTHALMIC REVIEW, I. p. 5.

I have the honour to be, Gentlemen,
Your obedient Servant,
W. ZEHENDER.

BERN, *Nov.* 29, 1864.

We republish the following letter from Dr. Mackenzie to Dr. Jago.

To JAMES JAGO, Esq., M.D., *Oxon.*, *A.B*, *Cantab.*

SIR,—At page 113 of your recent work, entitled "Entoptics, with its Uses in Physiology and Medicine," you state that a paper by you might possibly have been the "incentive" to my publishing on the same subject; and at page 125 you say that you "believe" that in drawing up the paper "On the Vision of Objects on and in the Eye," published by me in the *Edinburgh Medical and Surgical Journal* for July, 1845, I had "made use" of the paper published by you in the *London Medical Gazette* of May 9th and 16th, in the same year, entitled "Points in the Physiology and Diseases of the Eye," and dated 12th March, 1845. That your paper was an "incentive" to the writing of mine, or that I "made use" of your paper in any way, I beg leave to say is a mistake.

My paper is dated 30th December, 1844; that being the day on which, after working by times at the subject for a considerable number of months, I finished a fair copy of the manuscript. Early in January, 1845, I transmitted the manuscript to Dr. Craigie, the editor of the *Medical and Surgical Journal*, in Edinburgh; after which I did not again see the paper, till the printer sent me a proof in April.

Having written to Dr. Craigie as to the date of his receiving my manuscript and sending it to the press, that gentleman writes me, under date 16th November, 1864, as follows:—

"On referring to the numbers for January and April, 1845, I find the receipt of your paper acknowledged in the April Number, No. 163, volume 63. This shows that the paper must have been received most probably after the 1st of January, 1845; and after all the arrangements for printing the January Number had been fixed, and probably well advanced. * * * *

"Your paper must have remained in my possession from the date of its receipt, which must have been before the 20th of March, 1845, probably in January, 1845, till the beginning of April, when it would be sent to the printing-office in due course. It is the second paper, and the process of printing must have been going on early in April, 1845."

I certainly read your paper when it appeared in the *Medical Gazette* in May;

but before that time the proof of my paper had been returned by me to the printer in Edinburgh. I am positive that in the interval of transmitting my manuscript to Dr. Craigie in January and the publication of my paper on the 1st of July, I neither added anything to it, nor altered it in any way, with the exception of a few merely verbal corrections on the proof.

Having the pen in my hand, I may notice one or two other things in your recent work, which regard myself.

At page 124, you say, that in the fourth edition of my "Practical Treatise on Diseases of the Eye," I append a long list of authorities on the subject in question, but often "neglect to tell what observations were theirs, so that one cannot be sure whether a given idea has originated" with myself. The Section on Myodesopia in my Practical Treatise is a reprint of the paper in the *Edinburgh Journal*, with the introductory part (about six pages) omitted. The authorities, in the paper, are printed at the bottom of the pages, in the Treatise at the end of the Section; and I am bold enough to say, that no one with the smallest degree of care or candour could fall into the supposition that they were cited with the negligence of which you accuse me. The citations are all of them, without one exception, explicit references to the labours of former observers.

To one or two omissions, perhaps, I should plead guilty. For example, I do not quote Scheiner,[*] for the experiment of obscuring the opposite side of the field of vision through a pin-hole, by passing an opaque body from right to left, or *vice versa*, between the eye and the pin-hole; or quote Le Cat,[†] for his modification of Scheiner's experiment, in seeing the shadow of a pin appear with its head downwards, when the pin is passed with its head upwards between the eye and the pin-hole. No intelligent reader could suppose, I hope, that when I mentioned experiments, known for centuries, I intended to pass them off as "originating" with myself. Having no pretension to the office of entoptical historian, I omitted the references to Scheiner and Le Cat, and spoke of the pin-hole and the pin as experiments "often used to excite inquiry in those commencing to study optics." You, also, make no reference to Scheiner, when you introduce the first of these experiments in your paper in the *Medical Gazette*;[‡] or to Le Cat, where you detail the second in your subsequent work, entitled "Ocular Spectres and Structures as Mutual Exponents;"[§] nay, were I disposed to be "critical," I should say you announce them, especially Scheiner's, in a way which might make a careless reader conclude they were something new. The investigation of muscæ volitantes by means of small beams of light, parallel, diverging, and converging, being not quite so familiar a matter as the experiment of Scheiner and its modification by Le Cat, I referred in my paper[||] to the *Histoire de l'Académie Royale des Sciences* for 1760, where the phenomena of muscæ, viewed with the aid of a pin-hole and with that of a microscope, are, as far as I know, first described. You talk (pages 112, 113, of your recent work) of your "recounting the history" of entoptical methods—of your giving "a critical history of entoptical writings in their order of precedence;" but in this, as well as in your previous publications, you omit all notice of the original observations recorded in this branch of science. With lynx-like eye, you detect the not very patent fact, that Listing's "Beitrag zur physiologischen Optik" could not have been published till July, 1845, or even later, but with a strange blindness to chronology (a sad defect in a historian—a "critical" historian too), you slur the date of my paper, telling us you have had no opportunity of seeing it.

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[*] Oculus, hoc est Fundamentum Opticum. (Experientia secunda. Res per foramen minutum visuntur radiis decussatis). Pag. 32. Oeniponti, 1619.

[†] Traité des Sensations et des Passions en général, et des Sens en particulier. Tome II.. page 507. Paris, 1767. An edition of Le Cat's Traité des Sens appears to have been published at Rouen in 1740; but this edition I have not seen.

[‡] Vol. I. for 1845, page 63.

[§] Page 4. London, 1856.

[||] *Edinburgh Medical and Surgical Journal*, vol. LXIV., page 48, Edinburgh, 1845.

At page 125, you represent me as having "conversed" with Brewster on the subject of muscæ. I do not say that I did. I never had the honour of doing so; but I received from that eminent philosopher a letter, in which he communicated to me some observations on the subject, in the same spirit of kindness with which he had previously pointed out* my error in assigning a progressive movement to the globules within the pearly spectrum—an error which, along with several other errors respecting myodesopia, I have long ago renounced.

At page 127, you say that I aver that eyes that are subject to muscæ are "always" either myopic or presbyopic. I do not exactly say so. What I say is, that eyes of normal conformation are "seldom" subject to muscæ; that is, to the habitual perception of the objects which, a few lines before, I stated to exist in all eyes, and which, when they occur in an exaggerated and annoying degree, form the disease called myodesopia. I add, that when a person complains "much" of muscæ, we always find him either myopic or presbyopic.

Opinion has been a good deal divided on this subject. De la Hire said that only presbyopes were troubled with muscæ; the Royal Academicians of Paris added, that myopos are not more exempt from them than presbyopes. Brewster tells us† that, although some of the phenomena of muscæ may be seen by persons of all ages and with the best eyes, "those which are more peculiarly entitled to the name are exceedingly common beyond the middle period of life." Wardrop says, "Short-sighted people are least liable to this affection."‡ Both entoptic and microsopic investigations have proved to Donders that, as age advances, the vitreous humour becomes richer in the corpuscles and filaments which cause muscæ.§ He afterwards adds that myopes are more troubled with muscæ than others.|| My impression has been, that those whose eyes are emmetropic and possess the power of accommodation in perfection, rarely, if ever, complain of myodesopia. On this point your experience appears to have been different. Further statistics must determine it.

You state it to be a reason alleged by me, why only myopic or presbyopic eyes are subject to muscæ, that "an accurate refocalizing of light, issuing from external points upon the retina, prevents their being projected thereon." Such optical reason would indeed be absurd; but I never said so. What I say is this,

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* "Transactions of the Royal Society of Edinburgh," vol. XV., p. 380. Edinburgh, 1843.

† Op. cit. p. 377.

‡ "Morbid Anatomy of the Human Eye," vol. II. page 223. London, 1818.

§ "Anomalies of Accommodation and Refraction of the Eye," p. 192. London, 1864.

|| Ib., p. 391.

that "the interception of the rays, proceeding from external objects by filaments, in front of the retina, or even the formation of magnified shadows by diffraction, produces comparatively little effect when the remainder of those rays are brought accurately to focal points upon that membrane." As I think, almost every one will perceive, I mean "comparatively little effect" upon the percipient organ. My notion, as I have further expressed it, is, that "dilution of the images of external objects [as in myopia and presbyopia] favours the perception of the muscæ, which, in their turn, are, to a certain extent, extinguished in perfect vision." I never imagined that entohyaloid spectra were dioptrically prevented from being formed in the perfect eye, but only that they passed unheeded by the percipient organ, till attention was particularly directed to them, and that, therefore, they did not; in such a case, produce myodesopia. It is when the rays of light fall upon the retina in a state of dissipation, as they do in myopia and presbyopia, that muscæ are most perceived; and hence it is that myopes and presbyopes find their myodesopia diminished by the aid of appropriate glasses.

This letter has much exceeded the limits I intended when I began it. For the correction of errors in my writings on the eye I shall always feel grateful, come from what source it may; but misquotation, misrepresentation, and unfounded insinuation of bad faith, neither I nor any one is bound to submit to without remonstrance. This, then, I am sorry to say, must be my excuse for addressing you on this occasion, and for doing so through the medium of the press.

I have the honour to be, Sir,
Your most obedient Servant,
W. MACKENZIE.

Glasgow, 21st Nov., 1864.

Communications have been received from Dr. Mackenzie (Glasgow); Professor Donders (Utrecht); R. B. Carter, Esq. (Stroud); Dr. Geo. Rainy (Glasgow); J. N. Radcliffe, Esq. (London); Dr. Bowman (Montreal); Dr. Liebreich (Paris); Dr. Kroll (Utrecht); Dr. W. Hess (Mayence); Dr. Benedikt (Vienna); Dr. Warlomont (Brussels); Dr. Jago (Truro); J. Vose Solomon, Esq. (Birmingham); Professor Zehender (Bern).

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